Abstract Title: Utilizing the ISS Mission as a Testbed to Develop Cognitive Communications Systems

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The ISS provides an excellent opportunity for pioneering artificial intelligence software to meet the challenges of real-time communications (comm) link management. This opportunity empowers the ISS Program to forge a testbed for developing cognitive communications systems for the benefit of the ISS mission, manned Low Earth Orbit (LEO) science programs and future planetary exploration programs.

In November, 1998, the Flight Operations Directorate (FOD) started the ISS Antenna Manager (IAM) project to develop a single processor supporting multiple comm satellite tracking for two different antenna systems. Further, the processor was developed to be highly adaptable as it supported the ISS mission through all assembly stages. The ISS mission mandated communications specialists with complete knowledge of when the ISS was about to lose or gain comm link service. The current specialty mandated cognizance of large sun-tracking solar arrays and thermal management panels in addition to the highly-dynamic satellite service schedules and rise/set tables. This mission requirement makes the ISS the ideal communications management analogue for future LEO space station and long-duration planetary exploration missions. Future missions, with their precision-pointed, dynamic, laser-based comm links, require complete autonomy for managing high-data rate communications systems. Development of cognitive communications management systems that permit any crew member or payload science specialist, regardless of experience level, to control communications is one of the greater benefits the ISS can offer new space exploration programs.

The IAM project met a new mission requirement never previously levied against US space-born communications systems management: process and display the orientation of large solar arrays and thermal control panels based on real-time joint angle telemetry. However, IAM leaves the actual communications availability assessment to human judgement, which introduces unwanted variability because each specialist has a different core of experience with comm link performance. Because the ISS utilizes two different frequency bands, dynamic structure can be occasionally translucent at one frequency while it can completely interdict service at the other frequency. The impact of articulating structure on the comm link can depend on its orientation at the time it impinges on the link. It can become easy for a human specialist to cross-associate experience at one frequency with experience at the other frequency. Additionally, the specialist's experience is incremental, occurring one nine-hour shift at a time. Only the IAM processor experiences the complete 24x7x365 communications link performance for both communications links but, it has no "learning capability." If the IAM processor could be endowed with a cognitive ability to remember past structure-induced comm link outages, based on its knowledge of the ISS position, attitude, communications gear, array joint angles and tracking accuracy, it could convey such experience to the human operator. It could also use its learned communications link behaviors to accurately convey the availability of future communications sessions. Further, the tool could remember how

accurately or inaccurately it predicted availability and correct future predictions based on past performance. The IAM tool could learn frequency-specific impacts due to spacecraft structures and pass that information along as “experience.” Such development would provide a single artificial intelligence processor that could provide two different experience bases. If it also “knew” the satellite service schedule, it could distinguish structure blockage from schedule or planet blockage and then quickly switch to another satellite. Alternatively, just as a human operator could judge, a cognizant comm system based on the IAM model could “know” that the blockage is not going to last very long and continue tracking a comm satellite, waiting for it to track away from structure. Ultimately, once this capability was fully developed and tested in the Mission Control Center, it could be transferred on-orbit to support development of operations concepts that include more advanced cognitive communications systems.

Future applications of this capability are easily foreseen because even more dynamic satellite constellations with more nodes and greater capability are coming. Currently, the ISS fully employs a 300 million bit-per-second (Mbps) return link for harvesting payload science. In the coming eighteen months, it will step up to 600 Mbps. Already there is talk of a 1.2 billion bit-per-second (Gbps) upgrade for the ISS and laser comm links have already been tested from the ISS. Every data rate upgrade mandates more complicated and sensitive communications equipment which implies greater expertise invested in the human operator. Future on-orbit cognizant comm systems will be needed to meet greater performance demands aboard larger, far more complicated spacecraft. In the LEO environment, the old-style one-satellite-per-spacecraft operations concept will give way to a new concept of a single customer spacecraft simultaneously using multiple comm satellites. Much more highly-dynamic manned LEO missions with decades of crew members potentially increase the demand for communications link performance. A cognizant on-board communications system will meet advanced communications demands from future LEO missions and future planetary missions.

The ISS has fledgling components of future exploration programs, both LEO and planetary. Further, the Flight Operations Directorate, through the IAM project, has already begun to develop a communications management system that attempts to solve advanced problems ideally represented by dynamic structure impacting scheduled satellite service. With an earnest project to integrate artificial intelligence into the IAM processor, the ISS Program could develop a cognizant communications system that could be adapted and transferred to future on-orbit avionics designs.

Short Abstract:

The ISS Program offers an outstanding opportunity to testbed cognizant communications systems concepts for future space exploration programs. An existing tool, the ISS Antenna Manager, provides a foundational basis in which to integrate artificial intelligence software to begin real-time development and testing for on-board communications systems management.